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size. The latter was finally fed thyroid and began to metamorphose within a week. Both tadpoles were almost albinotic and from a recent paper by Allen it seems possible that in both larvae the hypophysis was abnormally developed or lacking. It is obvious that the production of a definite hormone and not the calory value of food is the limiting factor for the duration of the larval period.

4. *Conclusion.*—The experiments show that *Drosophila* has a temperature coefficient for the duration of life of the order of magnitude of that of a chemical reaction. Since the animals used in our experiments were absolutely free from microorganisms this influence of temperature on the duration of life cannot be attributed to bacterial poisons.

It was found, moreover, that the duration of the pupa stage is at each temperature proportional to the duration of the larval stage and that the same proportionality exists between the duration of the life of the insect to the larval stage, as far as our present experiments go. Since we know that the duration of the larval stage is determined by a specific hormone we are compelled to consider the possibility that the duration of life is also primarily determined by the formation of poisonous substances or a hormone in the body.

¹ Loeb, J., *Arch. ges. Physiol., Bonn*, 124, 1908, (411); Moore, A. R., *Arch. Entw.-Mech., Leipzig*, 29, 1910, (287). For a fuller discussion of the subject see Loeb, *The Organism as a Whole*, New York, 1916.

² Loeb, J., and Northrop, J. H., these PROCEEDINGS, 2, 1916, (456).

³ The experiments on the duration of life of the imago at 10° and 15° are not yet completed. From present indications it seems that for 15° the duration of life is in the neighborhood of ninety days, which agrees with the value expected according to the theory. At 10° the flies have been alive for ninety days and have not yet begun to die.

THE INTERRELATION BETWEEN DIET AND BODY CONDITION AND THE ENERGY PRODUCTION DURING MECHANICAL WORK IN THE DOG

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A dog weighing 8 kgm., in poor nutritive condition, was received into the laboratory. His basal metabolism, as measured during a period of absolute rest eighteen hours after partaking of an adequate standard diet, was 17.6 calories per hour. Traveling at the rate of 2.5 miles (4.0 km.) per hour he required 11.0 calories above the basal to move his body 1000 meters during the period beginning about eighteen hours after food ingestion, whereas 11.2 calories were required if 70 grams of

glucose had been administered immediately before the experiment began. These facts appear in the following table:

The interrelation between diet and body condition and the energy production during mechanical work in the dog

CONDITIONS	NUMBER OF EXPERIMENTS	WEIGHT IN KILO-GRAMS	CALORIES OF METABOLISM	RESPIRATORY QUOTIENT	WORK IN DISTANCE TRAVELED PER HOUR		CALORIES ABOVE THE BASAL PER 1000 METERS	ENERGY IN KILO-GRAMS TO MOVE 1 KGM. 1 METER
					Miles	Meters		
Basal	1	8.0	17.6	0.84				
Work, no food	1	8.3	60.7	0.78	2.48	3925	11.0	0.585
Work, glucose 70 grams	2	8.4	63.4	1.00	2.51	4170	11.2	0.566
Basal	4	9.1	17.2	0.85				
Work, no food	4	9.2	76.8	0.80	2.95	4760	12.4	0.578
Work + glucose, 70 grams	2	9.6	76.6	0.94	2.95	4750	12.5	0.550
Work + glucose, 100 grams	1	9.7	76.4	0.95	2.94	4740	12.5	0.550
Rest + glucose, 70 grams	2	9.3	20.7	1.05				
Work + meat, 750 grams	1	9.6	92.4	0.80	2.91	4700	16.0	0.708
Rest + meat, 750 grams	1	9.6	29.7	0.83				
Work + alanin, 20 grams	1	9.3	82.0	0.78	2.96	4780	13.6	0.620
Rest + alanin, 20 ^g grams	1	9.4	21.1	0.84				
Fasting								
Day 3 + work		8.75	72.4	0.72	2.97	4800	11.7	0.569
4		8.6	16.1	0.73				
5 + work		8.55	70.1	0.73	2.94	4750	11.4	0.567
7		8.35	15.2	0.74				
8		8.10	14.2	0.71				
8 + work		8.10	70.6	0.72	3.11	5020	11.2	0.588
13		7.60	12.4	0.74				
13 + work		7.60	62.5	0.72	2.92	4710	10.6	0.595
15		7.45	13.0	0.73				

In a second series of experiments begun after an interval of six weeks, during which time the dog had added a kilogram to his body weight, it was found that when he moved at the rate of 2.95 miles (4.75 km.) per hour 12.4 calories were required to propel his body 1000 meters if the dog had been given no food in the morning, and 12.5 calories were required when 70 or even 100 grams of glucose had been administered. The rise in the respiratory quotient demonstrates the influx of glucose molecules for use in the cells for the production of power, and yet this influx caused no increase whatever in the heat production.

On the eighth day of fasting, when the body weight had fallen to 8.1

kgm. (the original weight of the dog), it required 11.2 calories to move the dog 1000 meters. On the thirteenth day of fasting, the basal heat production having fallen to 14.2 calories, it required 10.6 calories to move the dog, now weighing 7.6 kgm., a distance of 1000 meters.

A loss of body weight of 19% accomplished through fasting was accompanied by a fall in the basal metabolism of 28%, and an economy in the fuel necessary to move the body 1000 meters amounting to 15%.

This method of calculation, however, does not give an accurate picture of the interrelation between the nutritive condition of the dog and the amount of energy of metabolism necessary to accomplish a given amount of mechanical work, for it is obvious that to move a body weight of 9.2 kgm. through 1000 meters of distance would require a greater amount of energy than to move a body weight of 7.6 kgm. over the same distance. When the computation is based upon the energy equivalent in kilogrammeters required to move 1 kgm. of body substance 1 meter through space, it is found that an average of 0.580 kilogrammeter is required for that purpose with a maximum variation of $\pm 2.5\%$ no matter what is the nutritive condition of the animal. (The reduction in this value after giving glucose in solution to the dog is dependent on the fact that the weight of the glucose solution (≈ 280 grams) was reckoned as part of the weight of the dog. The carrying of this inert mass, however, did not appreciably increase the level of metabolism, as has already been set forth above.)

One may conclude, therefore, that *the accomplishment of a given amount of mechanical work is always at the expense of a given amount of energy, and that the amount of energy required for mechanical work is independent of the physical condition of the subject and independent of the quantity of carbohydrate food present in the gastrointestinal tract.*

No experiments have been made after giving fat but, since the authorities (Zuntz, Atwater and Benedict) are agreed upon the equal economy of iso-dynamic values of these two classes of food substances in the production of a given amount of mechanical work, it may be assumed that ingested fat acts like carbohydrate in metabolism when work is performed.

When meat is ingested the situation changes. Meat is a stimulant of the metabolism, as are several of its component amino-acids. The effect of work upon the heat production during the fifth and sixth hours after giving 750 grams of meat, and during the third and fourth hours after giving 20 grams of alanin, is summarized in the following table:

Chart indicating the influence of meat and of alanin upon the energy production during mechanical work in the dog

	<i>Calories of metabolism per hour</i>
Rest after meat, 750 grams	29.7
Basal	17.2
Difference	12.5
Work + meat, 750 grams	92.4
Work, no food	76.8
Difference	15.6
Rest + alanin, 20 grams	21.1
Basal	17.2
Difference	3.9
Work + alanin, 20 grams	82.0
Work, no food	76.8
Difference	5.2

It is apparent that meat acts as a stimulant to metabolism, raising not only the level of the basal metabolism but even increasing the quantity of additional energy required to move the dog, above the quantity to be expected were there a summation between the effect of protein stimulation and work to be accomplished. The same holds true of alanin, a simple cleavage product of meat which, in metabolism, is convertible into lactic or pyruvic acid, either of which may be transformed into glucose. Clear and sharp cut appears the distinction between the behavior of glucose itself and of alanin, which is convertible into glucose but whose intermediary acid products constitute a direct stimulus to metabolism, while the metabolites of glucose do not.

Summarizing, one may conclude:

1. Protein in the dietary is primarily for the repair of the tissues. It is not beneficial for the economical performance of work. In excess, it largely increases the heat production which a working organism is called on to eliminate.

2. One may reduce the basal requirement for energy by starvation, and this process may economize food in the case of those who do no mechanical work.

3. To accomplish a given amount of work a given amount of fuel energy is required, irrespective of the nutritive condition of the organism. This is of primary importance in the maintenance of armies or munition workers. Carbohydrate food fuel is utilized without loss.

4. Upon the capacity for heroism in the farmer will depend in the immediate future the security of the world.